Spatial Correlations of Anomaly Time Series of AIRS Version-6 Land Surface Skin Temperatures with the Niño-4 Index

Joel Susskind
NASA Goddard Space Flight Center
Code 610, Earth Sciences Division
Greenbelt, MD 20771
Joel.Susskind@nasa.gov

Jae N. Lee
Jae.N.Lee@nasa.gov

Lena Iredell
Lena.Iredell@nasa.gov

For questions or comments during AGU poster session call:
Joel Susskind (240) 793-6398

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Background Information

The AIRS Science Team AIRS/AMSU Version-6 Data Set

AIRS is the advanced IR Sounder flying on EOS Aqua accompanied by AMSU, an advanced microwave sounder. There are 9 AIRS 15 km x 15 km Fields of View (FOV's) within a single AMSU A 45 km x 45 km Field of Regard (FOR). AIRS products include land/ocean/ice surface skin temperature T_{skin}, atmospheric temperature profile T(p), water vapor profile q(p), and trace gas profiles; fractional cloud cover and cloud top pressure; and Outgoing Longwave Radiation (OLR). Most level-2 (single retrieval) products are generated on an AMSU FOR, but cloud products and OLR are generated for each AIRS FOV. Successful Quality Controlled AIRS soundings are generated in up to 90% fractional cloud cover. Level-3 products are gridded separately for 1:30 AM orbits and 1:30 PM orbits on a global 1˚x 1˚ spatial grid on a daily, eight day, and monthly mean basis.

Improved AIRS Version-6 Surface Skin Parameters

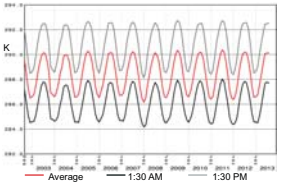
AIRS Version-6 has many significant improvements in retrieval methodology over the previously operational Version-5 retrieval algorithm. The surface skin temperatures are determined over all spatial domains using observations in 36 shortwave window channels in the spectral range 2420 cm^{-1} to 2664 cm^{-1}, simultaneously with shortwave surface spectral emissivity and surface spectral bi-directional reflectance of solar radiation. Longwave surface spectral emissivity is determined in a subsequent step using 77 channels in the long wave window region between 758 cm^{-1} and 1250 cm^{-1}.

Data Sets Used in This Study

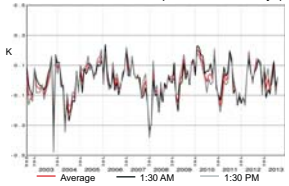
AIRS Science Team Version-6 monthly mean level-3 data for skin temperature and cloud fraction, each gridded separately for 1:30 AM and 1:30 PM

- Data products used extend from September 2002 (the start of the data set) to August 2013.
- Eleven-year monthly mean climatologies were generated for each grid box by averaging monthly mean data for all Januaries, Februaries, etc.
- Separate climatologies were generated for 1:30 PM and 1:30 AM
- The monthly anomaly for each grid box is the difference of the value for that month from that month's climatology.

Global Mean Surface Skin Temperature (K)

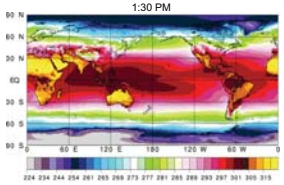


Global Mean Surface Temperature Anomaly (K)



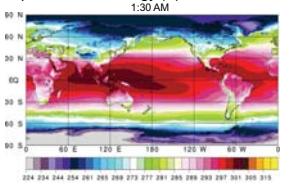
Annual Mean Surface Skin Temperature Climatology (K)

1:30 PM



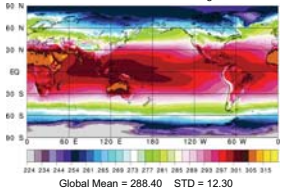
Global Mean = 290.72 STD = 13.40

1:30 AM



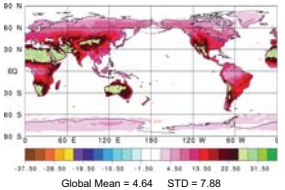
Global Mean = 286.08 STD = 12.40

1:30 PM/1:30 AM Average



Global Mean = 288.40 STD = 12.30

1:30 PM minus 1:30 AM



Global Mean = 4.64 STD = 7.88

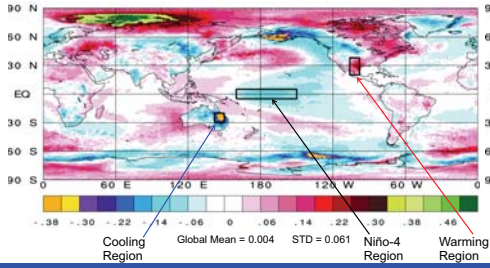
Eleven Year Anomaly Trends and Correlations with El Niño Index

ARCs and ENCs

The Average Rate of Change (ARC) for a grid box is defined as the slope of the straight line fit passing through the monthly anomaly time series. ARC's represent short-term trends. Values of ARC's depend on the extent of the time series used. Spatial patterns of ARCs are more important than their precise values.

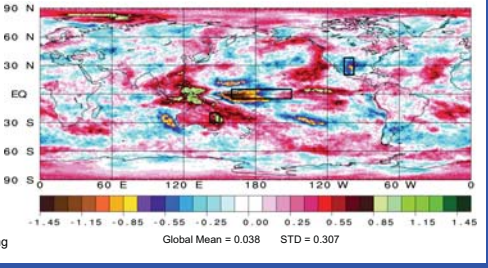
The El Nino Correlation (ENC) for a grid box is the correlation of the anomaly time series for that grid box with the NOAA Niño-4 Index, which we define as the monthly mean sea surface temperature averaged over the NOAA Niño-4 region, minus its 11 year climatology. There was a strong El Niño in 2002 and a strong La Niña in 2010. Consequently, the ARC of the Niño-4 Index over this time period is negative. The ENC of the Niño-4 Index is by definition 1.0.

AIRS T_{skin} ARC (K/yr)
September 2002 through August 2013
1:30 AM/1:30 PM Average



Global Mean = 0.004 STD = 0.061

AIRS Cloud Fraction ARC (%/yr)
September 2002 through August 2013
1:30 AM/1:30 PM Average



Global Mean = 0.038 STD = 0.307

Eleven Year Changes in Surface Skin Temperature

The global mean surface skin temperature did not change considerably over the period 2002 through 2013, but substantial regional changes took place. Changes in skin temperature are spatially related to changes in cloud cover. The Niño-4 region cooled over this time period, and most of this region had a significant decrease in cloud cover. Some land areas cooled considerably over this time period, with corresponding significant increases in cloud cover, and others warmed, with corresponding decreases in cloud cover. Significant changes in skin temperature in these land areas occurred during the day (1:30 PM) but not at night (1:30 AM). ENCs of skin temperature in cooling (warming) land areas tend to be highly positive (negative) during the day, and less so at night. ENCs of cloud cover in these land areas behave similarly to those of skin temperature, but are of opposite sign. This shows that El Niño/La Niña activity is the driving force behind some large local changes in land skin temperature . The short term warming at high Northern latitudes appears to be unrelated to El Niño activity.

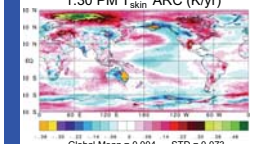
Summary

The AIRS Science Team Version-6 data set is a valuable resource for meteorological studies. Quality Controlled earth's surface skin temperatures are produced on a 45 km x 45 km spatial scale under most cloud cover conditions. The same retrieval algorithm is used for all surface types under all conditions. This study used eleven years of AIRS monthly mean surface skin temperature and cloud cover products to show that land surface skin temperatures have decreased significantly in some areas and increased significantly in other areas over the period September 2002 through August 2013. These changes occurred primarily at 1:30 PM but not at 1:30 AM. Cooling land areas contained corresponding increases in cloud cover over this time period, with the reverse being true for warming land areas. The cloud cover anomaly patterns for a given month are affected significantly by El Niño/La Niña activity, and anomalies in cloud cover are a driving force behind anomalies in land surface skin temperature.

AIRS level-2 (retrieval by retrieval) and level-3 1° x 1° gridded products can be obtained at the Goddard DISC http://disc.sci.gsfc.nasa.gov/AIRS/data-holdings. The AIRS instrument is extremely stable, and accurate AIRS products are expected to continue until at least 2022.

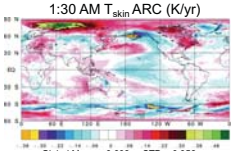
ARCs and ENCs September 2002 through August 2013

1:30 PM T_{skin} ARC (K/yr)



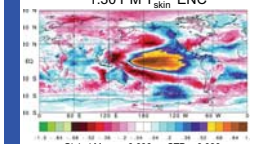
Global Mean = 0.004 STD = 0.073

1:30 AM T_{skin} ARC (K/yr)



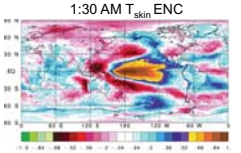
Global Mean = 0.003 STD = 0.056

1:30 PM T_{skin} ENC



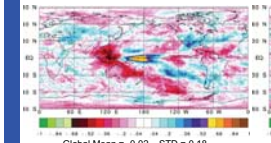
Global Mean = 0.006 STD = 0.030

1:30 AM T_{skin} ENC



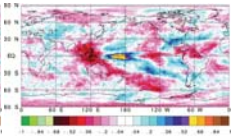
Global Mean = 0.006 STD = 0.030

1:30 PM Cloud Fraction ENC



Global Mean = -0.02 STD = 0.18

1:30 AM Cloud Fraction ENC

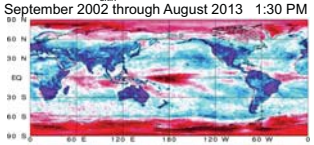


Global Mean = - 0.03 STD = 0.18

Correlations of Skin Temperature Anomalies with those of Cloud Cover

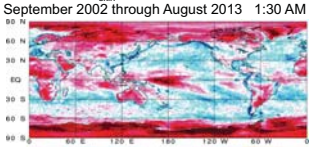
El Niño/La Niña activity affects the spatial distribution of anomalies of cloud cover, but does not directly affect land skin temperature anomalies. Rather, skin temperature anomalies over land are affected to a great extent by cloud fraction anomalies, and associated precipitation anomalies, especially during the day. Over most non-polar land areas, land skin temperature anomalies are highly negatively correlated with cloud fraction anomalies during the day (clear areas warm more during the day) and tend to be positively correlated with cloud fraction anomalies at night (clearer areas cool more at night). Polar land areas have positive skin temperature and cloud cover anomaly correlations both day and night (warmer time periods generate more cloud cover). Anomaly correlations over ocean are spatially complex, but do not change appreciably from day to night.

Correlation of T_{skin} and Cloud Fraction Anomalies
September 2002 through August 2013 1:30 PM



Global Mean = -0.13 STD = 0.28

Correlation of T_{skin} and Cloud Fraction Anomalies
September 2002 through August 2013 1:30 AM



Global Mean = 0.03 STD = 0.25

Examples of area weighted skin temperature and cloud cover anomaly time series, and their correlations, are shown below for the cooling box and the warming box.